ARS 42-120
September 1966

UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Service

MODULATING VALVE FOR PROGRAMMED TEMPERATURE

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The need for greater versatility in control of various environmental factors continues to increase. Much more investigational research and product processing are now being conducted under controlled, or modified, environments than ever before. More environmental factors are being controlled. One of the most important of these is temperature, which is usually given first and close attention in any contemplated environmental control system.

Temperature control may be a relatively simple procedure for some applications or it may involve complex procedures and equipment under more involved conditions. Where programming and control of temperature are necessary throughout a range extending both above and below ambient, some means of both cooling and heating are required in the control system. Various systems of control may be used to obtain the desired temperatures in a program. One such system involves the mixing of heated and cooled liquids in varying proportions to obtain a liquid at the indicated control-point temperature. The requisite mixing is usually accomplished by use of valves that are regulated to obtain the required proportioning of hot and cold liquids.

Several types of valves of various designs that can be used for liquid mixing are available from commercial sources. Some valves that are available however, are restricted in use to limited or specific applications; or, when suitable for use, they must be used in multiple to accomplish complete system control. Also, valves that may be commercially available, and suitable for limited-application temperature control, are not readily adaptable to programming over a wide temperature range.

VALVE FOR SPECIFIC APPLICATION

In several areas of research with plants and animals and also in other than biological fields, regulation of various environmental factors, including temperature, is required. The initiation of a project for the design and development of an environmental cabinet that would be suitable for poultry disease research, under controlled environments, emphasized the need for a relatively simple, compact, inexpensive but effective device by which programmed control of modulated temperature could be achieved in a climate control system.

The general design criteria and parameters selected to meet the needs for this specific application were:

(a) The range of programmed temperature should include from 0° to 140° F.
(b) Temperature programming could be on a cyclical basis.
(c) Valve and liquid circulation system components must be compatible with the liquid to be circulated, and at temperatures within -10° to 165° range.
(d) Liquid for heat transfer should be near-clear, and noncorrosive.

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(e) Circulation of liquid to heat transfer surfaces must be continuous full-flow.

(f) Supply liquid for temperature modulation of circulated liquid would be drawn from hot and cold supply tanks only when temperature change of circulated liquid was required.

(g) Liquid would be returned to same supply tank at the same rate from which it was drawn.

To meet these requirements, a liquid circulation system was arranged as shown in a diagram (fig. 1). This arrangement makes use of a 7-way valve that may be of either rotary or of linear construction and that may be actuated by either rotary or linear motor. Figure 2 shows installation drawing of a 7-way rotary modulating valve.

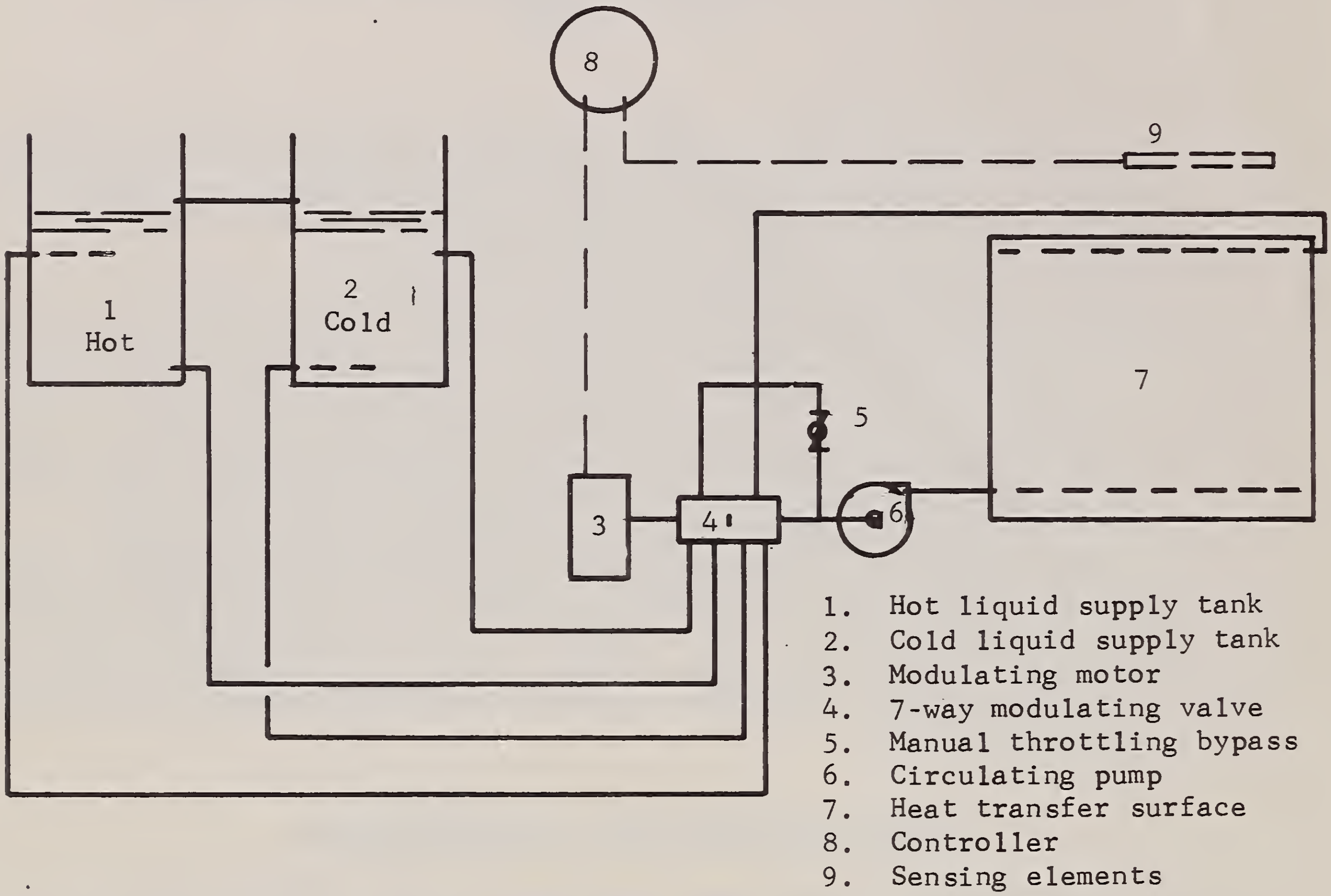

Figure 1.--Diagrammatic layout of temperature control liquid circulation system with 7-way modulating valve.

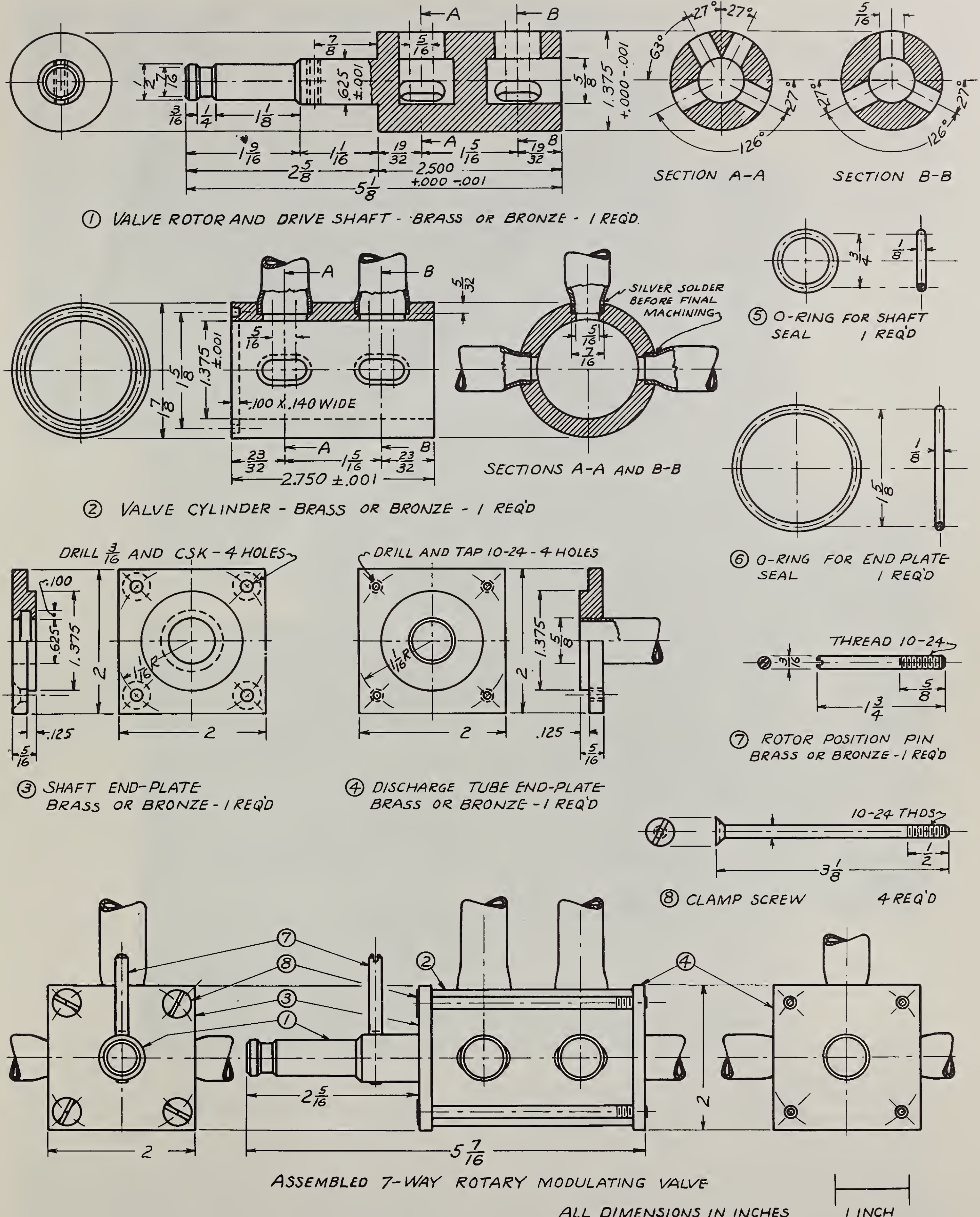

Figure 2.--Installation drawing of 7-way rotary modulating valve.

VALVE DESIGN AND CONSTRUCTION

The valve design, as shown in figure 2, may be readily produced in any reasonably well-equipped shop. Figure 3, A, shows a view of the valve and figure 3, B, shows a disassembled view of component parts. (The size of the valve is indicated by the pipe included in the photograph.)

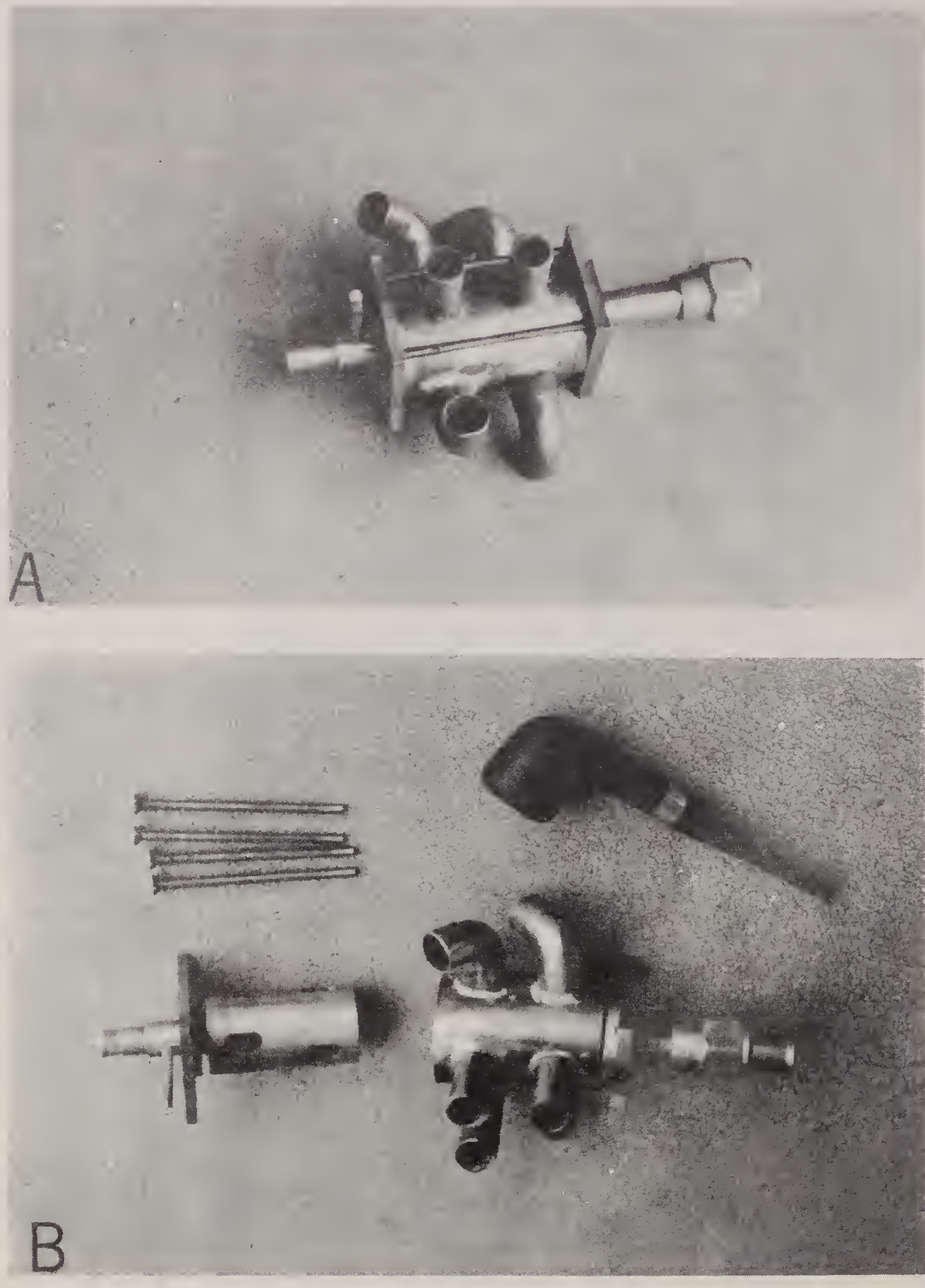

Figure 3.--A 7-way rotary modulating valve for temperature regulation: A, An assembled view; B, disassembled view of component parts. (The size of the valve is indicated by the pipe included in the photograph.)

This rotary modulating valve requires no support other than the connected supply tubing. Figures 4 and 5 show the installation of several valves, in multiple controls. In these installations, the check valves shown are not essential for successful performance of the valves.

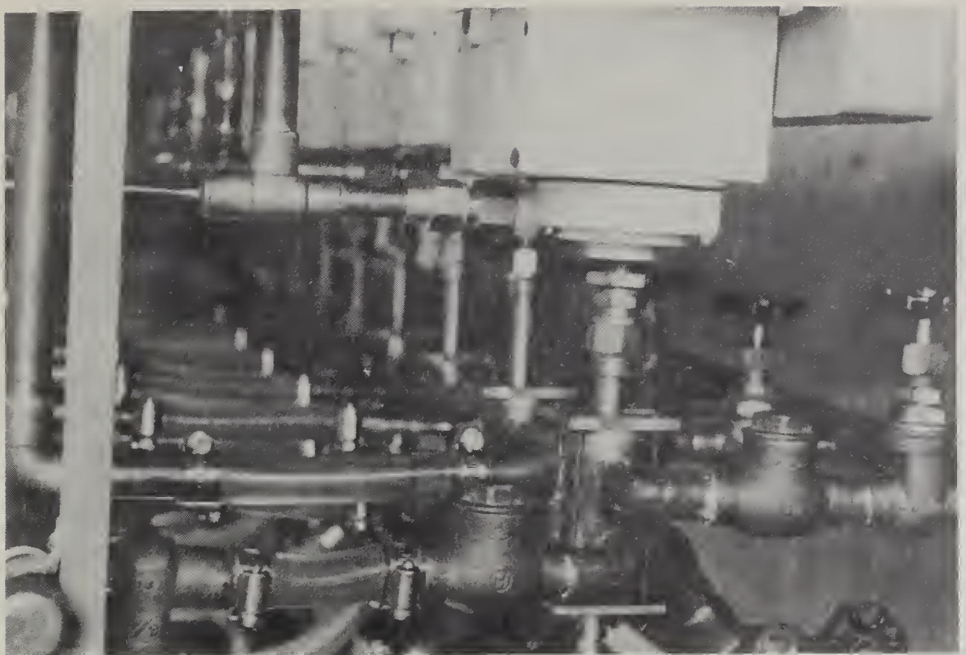

Figure 4.--Rotary modulating valve in multiple application for climatic control.

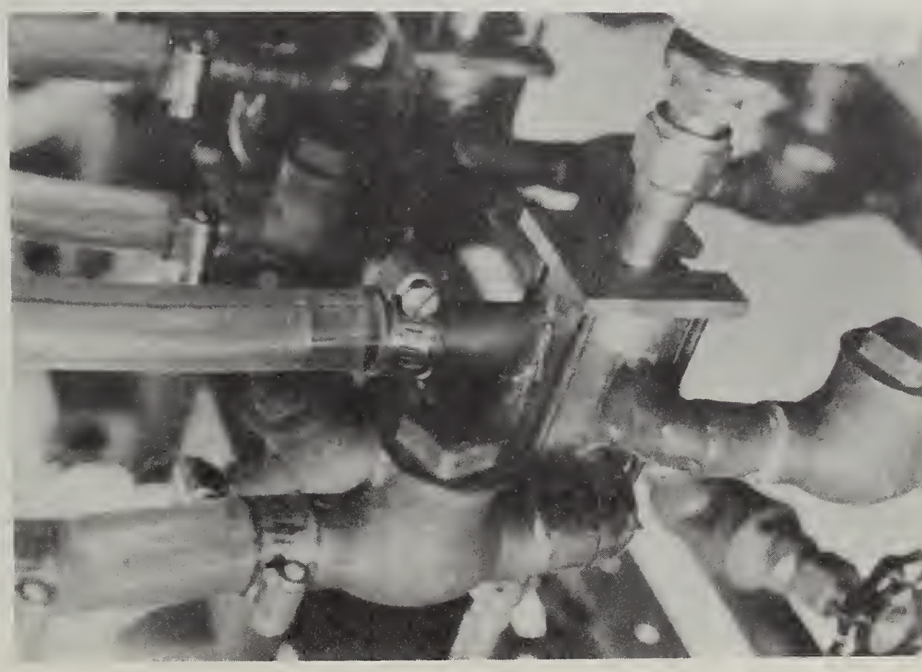

Figure 5.--Closeup of 7-way rotary modulating valve. Check valves shown are not essential for valve operation.

VALVE PERFORMANCE

During operation, the rotor of the modulating valve is positioned in response to signals transmitted by the system controller to the valve drive motor. A standard, commercially available controller with programmed or fixed set-point may be used. The controller continuously senses the temperature of the controlled element, compares the sensed temperature with that of the existing set-point, and transmits to the valve actuating motor a corrective signal that positions the valve rotor to rectify difference between sensed and set-point temperatures. Corrective action may be to either raise or lower the temperature of the liquid in contact with the heat transfer surface. Various types of controller response are available. The resultant action of the final control device is somewhat dependent on the type of control action initiated

by the controller. When difference between sensed and set-point temperature is within a preselected and acceptable range, no signal is transmitted to the valve driving motor and the valve rotor remains in the existing position. A look at figure 2 shows that, regardless of valve rotor position, liquid will be circulated in contact with the heat transfer surface. This liquid may be supplied by recirculation, by partial supply from the cold tank mixing with partial recirculation, or by partial supply from the hot supply tank mixed with partial recirculation.

With the valve rotor in mid-position, the recirculation port is in alinement and the discharge port is closed, thus full-flow recirculation of controlled liquid is provided. In this position, both hot and cold supply and return ports are closed so no liquid is drawn from or returned to the supply tanks.

When imbalance occurs between sensed and set-point temperatures, the valve rotor is repositioned so as to correct the imbalance. As the valve rotor is rotated to left or right the valve port-to-pump remains fully open; the recirculation port moves to close; the discharge port moves to open; one supply port (hot or cold) and the corresponding return port move to open. The extent and nature of the movement are controlled by the extent of the temperature imbalance and the type of corrective action transmitted by the controller. The response obtained depends also on the valve port shape and size.

To achieve satisfactory temperature modulation, it is not necessary that the valve provide complete shut-off. Should some leakage occur (as it will with the valve as constructed) the rotor is automatically positioned by the controller to compensate.

Valve performance can be altered by alterations in design. It can also be modified by manual throttling of supply and/or return lines. Throttling of supply lines, where an oversize modulating valve is used, can be effective in reducing or preventing overshoot and undershoot during corrective control action. Proper sizing of valve to load requirements will improve control action, but this is not always easy, or even possible, where load varies widely as is usually the case under programmed schedules.

The control obtained with use of a given valve depends on several factors, including the controller and its action. Figure 6 shows a chart record of a repeated cycle of programmed temperature, before adjustment or modification of control action by the valve described in this report. The controller used was equipped with a direct-acting potentiometer matched to the modulating motor that actuated the valve rotor. The recorded temperature shown by the chart is that of the mean temperature of the liquid in circulation contact with the controlled heat transfer surface. This surface was a flat aluminum plate of approximately 1/32-inch thickness with liquid contact on one side and low velocity air on the other side.

Where the temperature of air is to be controlled or programmed, it is usual to regulate the temperature of a heat transfer surface, which in turn effects control of the air passing in contact with the controlled but transfer surface. Figure 7 shows a single cycle of programmed air temperature as obtained by use of the 7-way modulating valve.

This valve also has been used for control of relative humidity by modulating heat transfer surface temperatures on a programmed basis below corresponding dewpoint temperatures, and for climatic control applications. By design and installation modifications, it is believed such a valve as reported in this publication could be used in a variety of applications at considerable reduction in cost, and with satisfactory performance results.

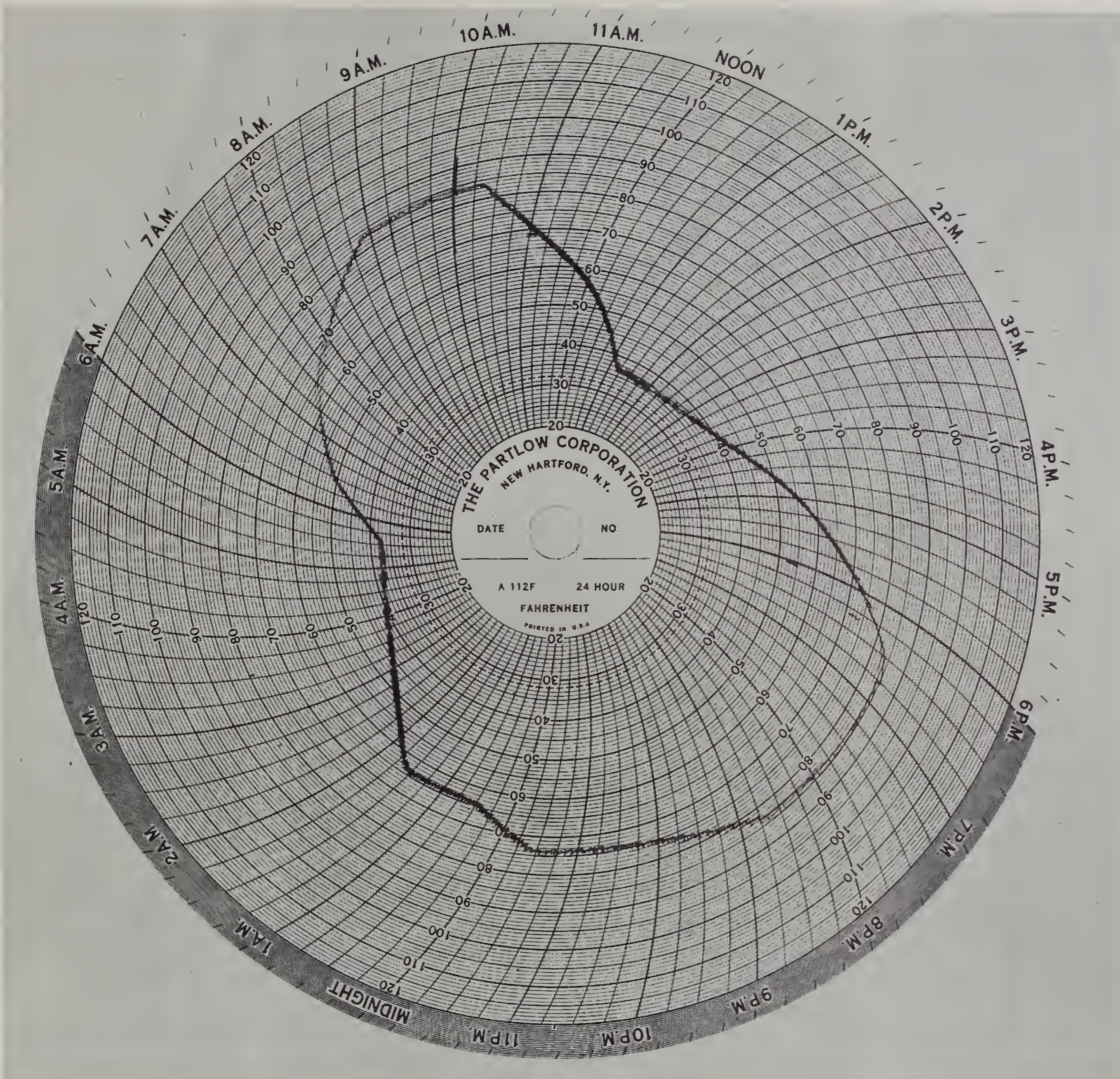

Figure 6.--Chart record of repeated cycle of programmed temperature. The chart shows temperature of controlled liquid.

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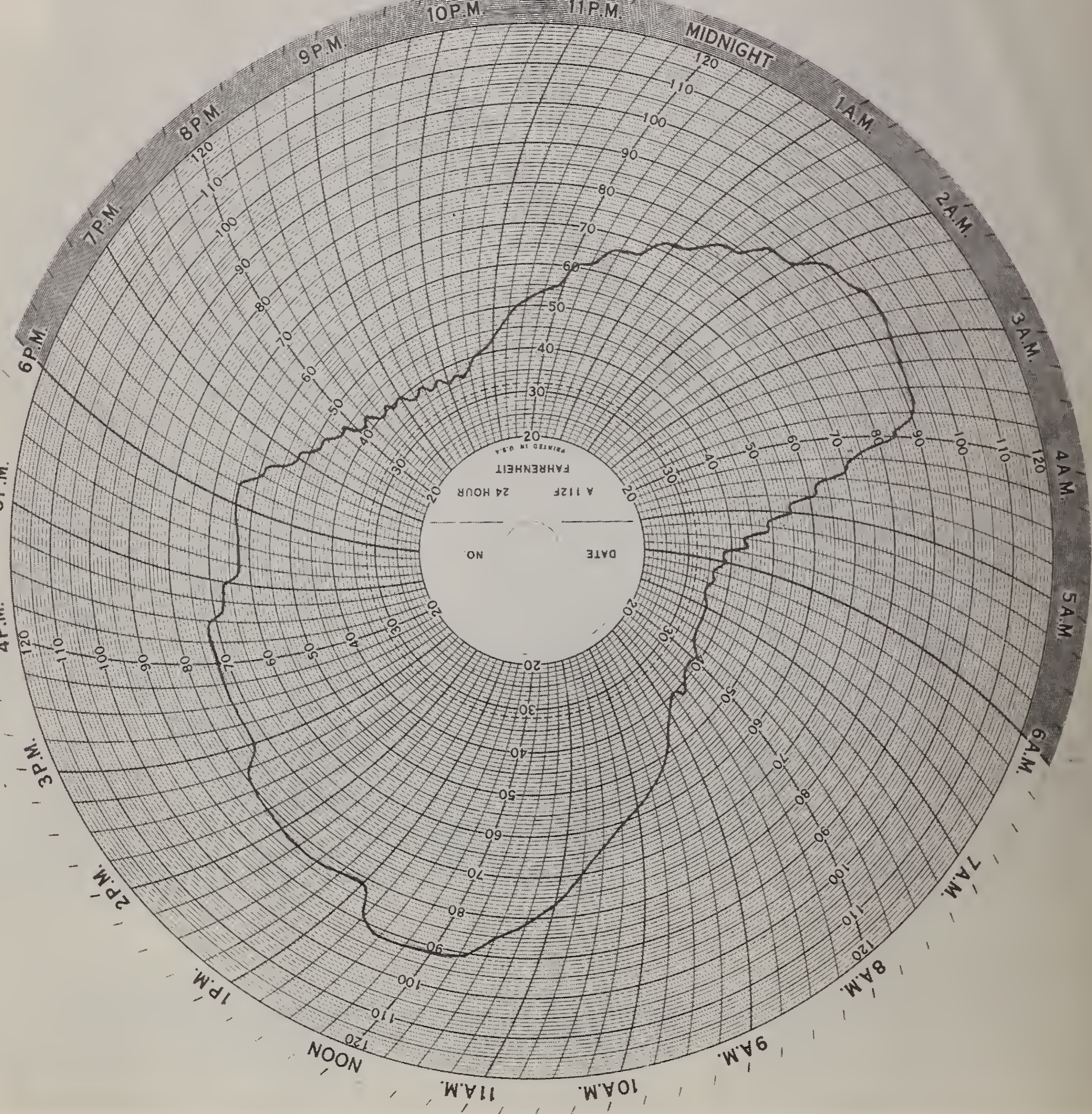

Figure 7.--Single cycle of programmed air temperature obtained by use of the 7-way modulating valve.